

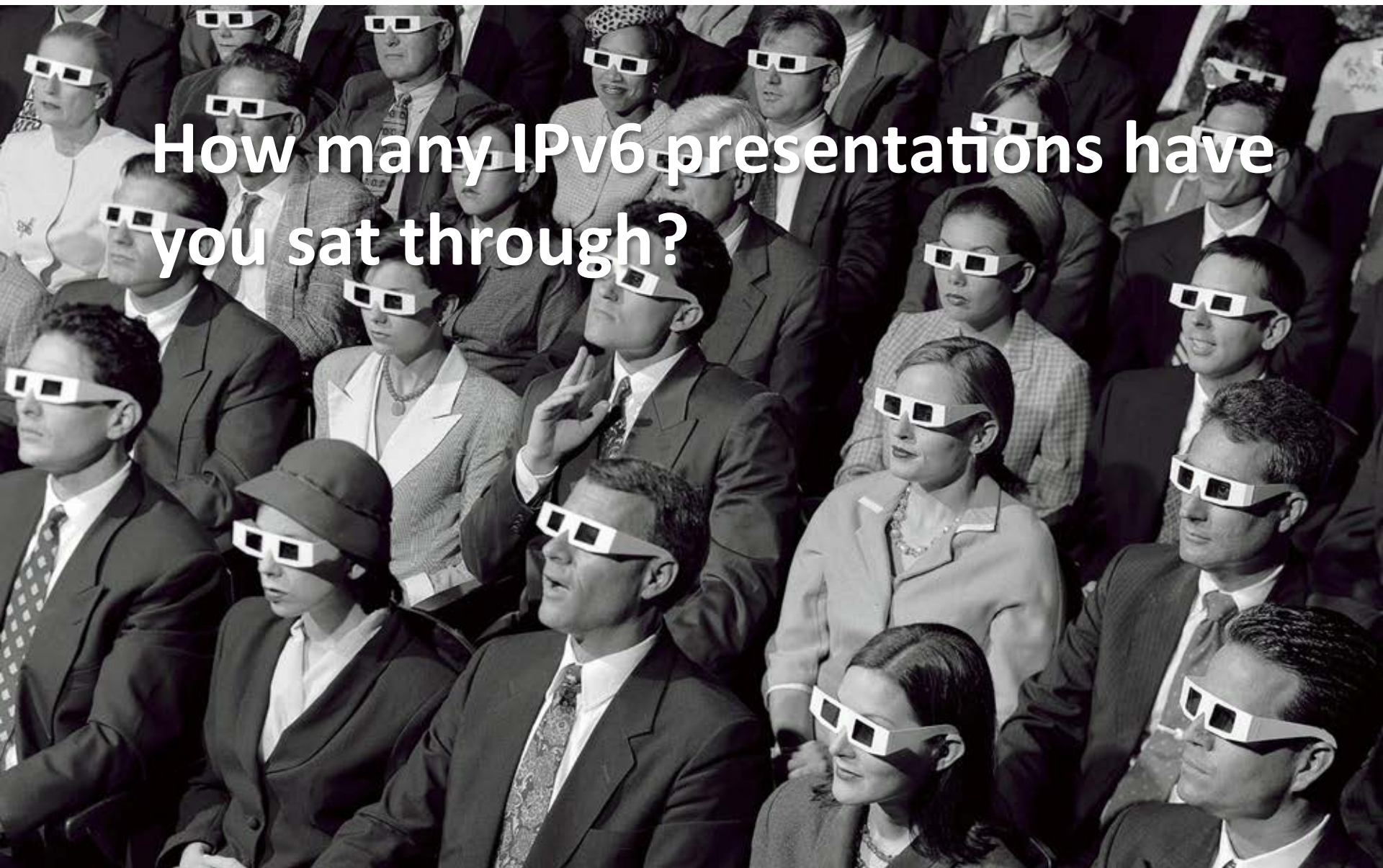
Are we there yet?

20 years of IPv6

Geoff Huston
APNIC

A question to each of you...

A question to each of you...



A question to each of you...



How many IPv6 presentations have you sat through?

- ☐ 20?
- ☐ 100?
- ☐ 1,000?
- ☐ I don't know!

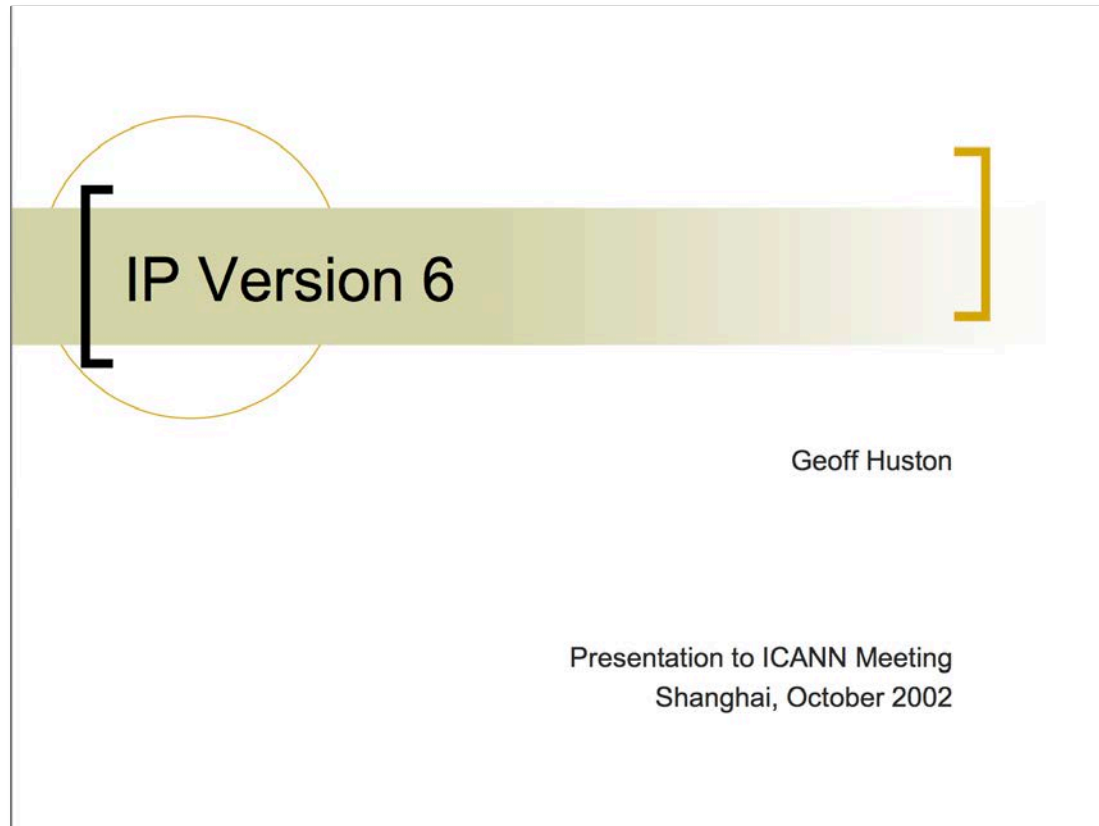
A reminder

In case you weren't paying attention at the time, here's a few extracts from my archives...

12 years ago, in China



12 years ago, in China



Geoff Huston

Presentation to ICANN Meeting
Shanghai, October 2002

On IPv6 Myths

[IPv6 vs IPv4]

- There is no compelling “feature” or aspect of V6 that does not have a functional counterpart in V4.
- Any industry adoption of V6 cannot be based on superior functionality of V6 over V4 as a protocol platform

The “anti-hype” message – IPv6 is not brighter, shiner, or more miraculous. It just has more addresses!

On IPv6 Myths

[IPv6 vs IPv4]

- **A view from Noel Chiappa:**

“The IPv6 community got into the corner it's in now because it took the path of least technical resistance: IPv6 looks a lot like IPv4 because we "know" that IPv4 "works". Well, guess what, IPv4 **doesn't** work, and IPng needed to look really different, and those of us who tried to tell the rest of the IETF that didn't get very far - although I think we gave it a pretty good try.

So if the IPv6 community again takes the path of least technical resistance, having not learned the first time around that that's really not the answer, God help you all”.

Posting to IETF multi6 WG, 26 Feb 2003

The “anti-hype” message – IPv6 is not brighter, shiner, or more miraculous. It just has more addresses!

Wavering in the ranks!

[The Bottom Line]

- Its looking like its a NAT vs V6 choice
 - And its not obvious that the market is going to correctly balance the longer term interest against very short term expediency

Moments of doubt and uncertainty!

2004: IPv6 Address Policies Revisited

Asia Pacific Network Information Centre

APNIC

2

It seems rather odd...

- To be considering address capacity issues in a technology that is really only ramping up.
- 128 bits allows an awesomely large pool of unique values
 - “If the earth were made entirely out of 1 cubic millimetre grains of sand, then you could give a unique address to each grain in 300 million planets the size of the earth” -- Wikipedia
- This is a highly speculative exercise....

Contemplating changing the HD Ratio and the 48 bit end site prefix.

“But you can’t do that! The installed base of IPv6 is too big to change!”

2005:

“One day man will travel
faster than a horse can run”

Rene Descarte

If this is all about guessing future requirements, then sometimes we can be both right and incredibly wrong at the same time!

2005: Redefining terms of engagement

It looks like the IPv6 future may well be “revolution” where IPv6 is forced into direct competition with existing IPv4+NAT networks

And the primary leverage here is one of “cheaper” and “bigger”, and not necessarily “better”

The emerging realization that IPv6 won't just happen in the same way that IPv4 just happened -- there are other factors at play here.

2006:

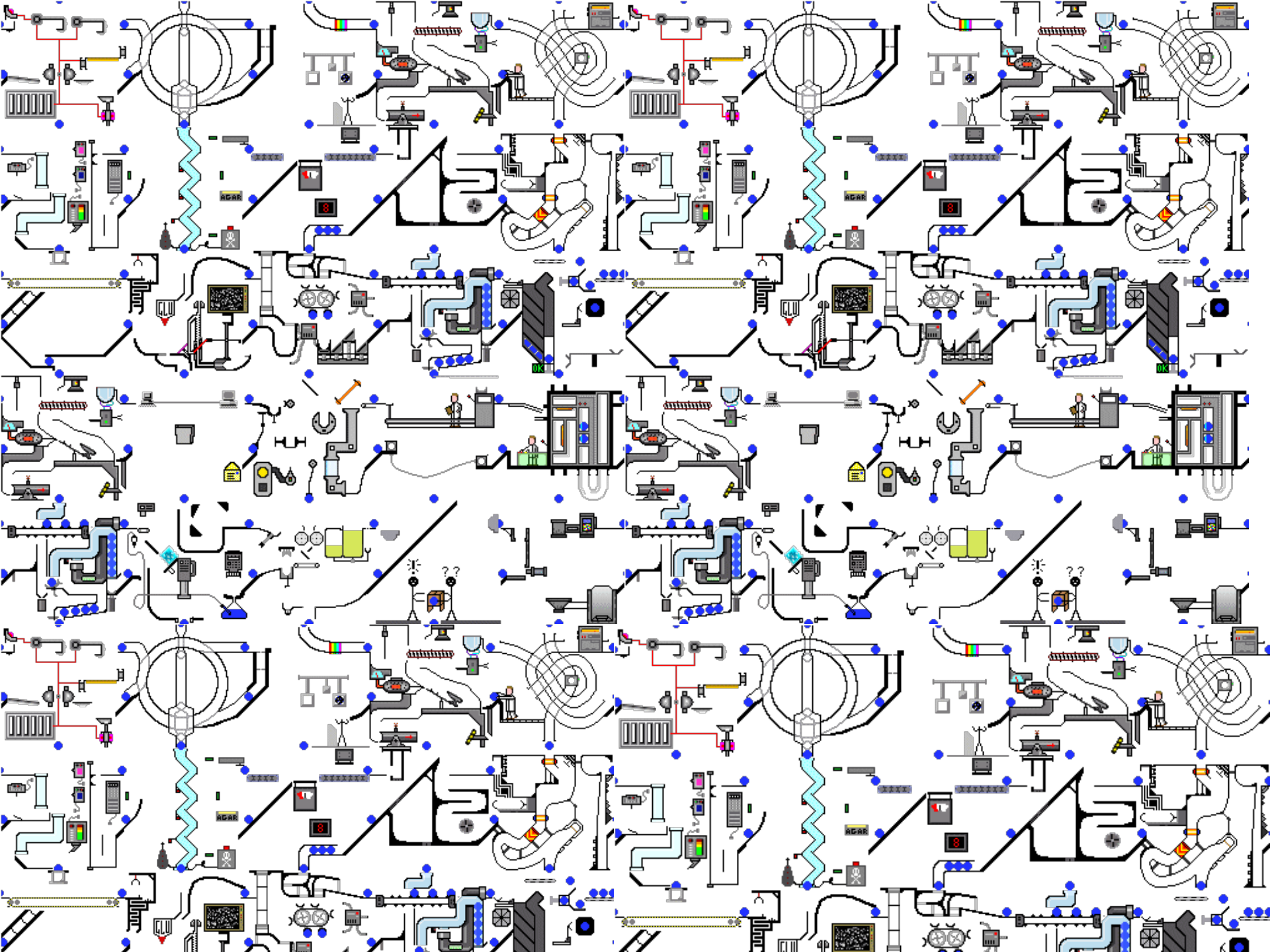
Technology – IPv6

- "IP with larger addresses"
- Address space requirements are no longer being easily met by IPv4
- This is an issue for high volume deployments including:
 - Pocket IP devices
 - Consumer devices
- IPv6 appears to offer reasonable technology solutions that preserve IP integrity, reduce middleware dependencies and allow full end-to-end IP functionality for a device-rich world

BUT

Noone wants to pay for widespread IPv6 deployment just yet!

Searching for drivers for IPv6 adoption



i could watch that for hours!

2007:

Maybe it's just deregulation

- Near term business pressures simply support the case for further deferral of IPv6 infrastructure investment
- There is insufficient linkage between the added cost, complexity and fragility of NAT-based applications at the edge and the costs of infrastructure deployment of IPv6 in the middle
 - Deregulated markets are not perfect information markets – pain becomes isolated from potential remedy

It's not just a technology issue – there are business drivers here as well

2008:

New Markets for IPv6?



The Universe of Tiny Things?

The world of billions of chattering devices unleashing new rivers of gold into the IP industry?

Or is this just the economy? There is no new money and these billions of chattering devices will generate much the same revenue as we have today

So we have to cram all these billions of new devices trillions of new packets into the same money that we have today.

technology leverage will make tomorrow's networks 1,000 times CHEAPER to deliver an IP packet than today's network?

Or have we reached some limit to the economic viability of communications that imply that ever smaller valued transactions can't be sustained over ever larger networks?

Do RFID and Bluetooth provide a different model of communication that is viable in the universe of things, where the identity is global but the communication is strictly limited in scope and

And if you ever are curious enough to enlarge this slide to see if there is text all the way down the page you will have got yourself to this point, where it becomes obvious that I've got nothing more to say and I want to fill up the bottom of the slide with tiny text.

2008

This is the time of the **“IPv4 exhaustion is coming. What are we going to do?”** presentations.

Lets dive into one of them for a few slides from 2008...



Total address demand

IANA Pool

Address Count (/8s)

Date

IANA Pool Assigned Advertised Unadvertised RIR Pool



That's 5th February 2011

<http://ipv4.potaroo.net>

That's 5th February 2011

yawn - seen all this before
It's now **BORING!**



<http://ipv4.potaroo.net>

That's a highly uncertain prediction - it could be out by as much as 18 months



I can't model changes in demand due to:

- Panic — last minute rush

- New Policies - “reservations” of remaining address space

- Change of relative IPv4 / IPv6 demands

And modeling uncertainty due to:

- highly skewed data used to make projections



That's sometime between
late 2009 and early 2011



That's sometime between
late 2009 and early 2011

~~SO WHAT?~~
we've all heard this before
nothing new to see here - move
along!

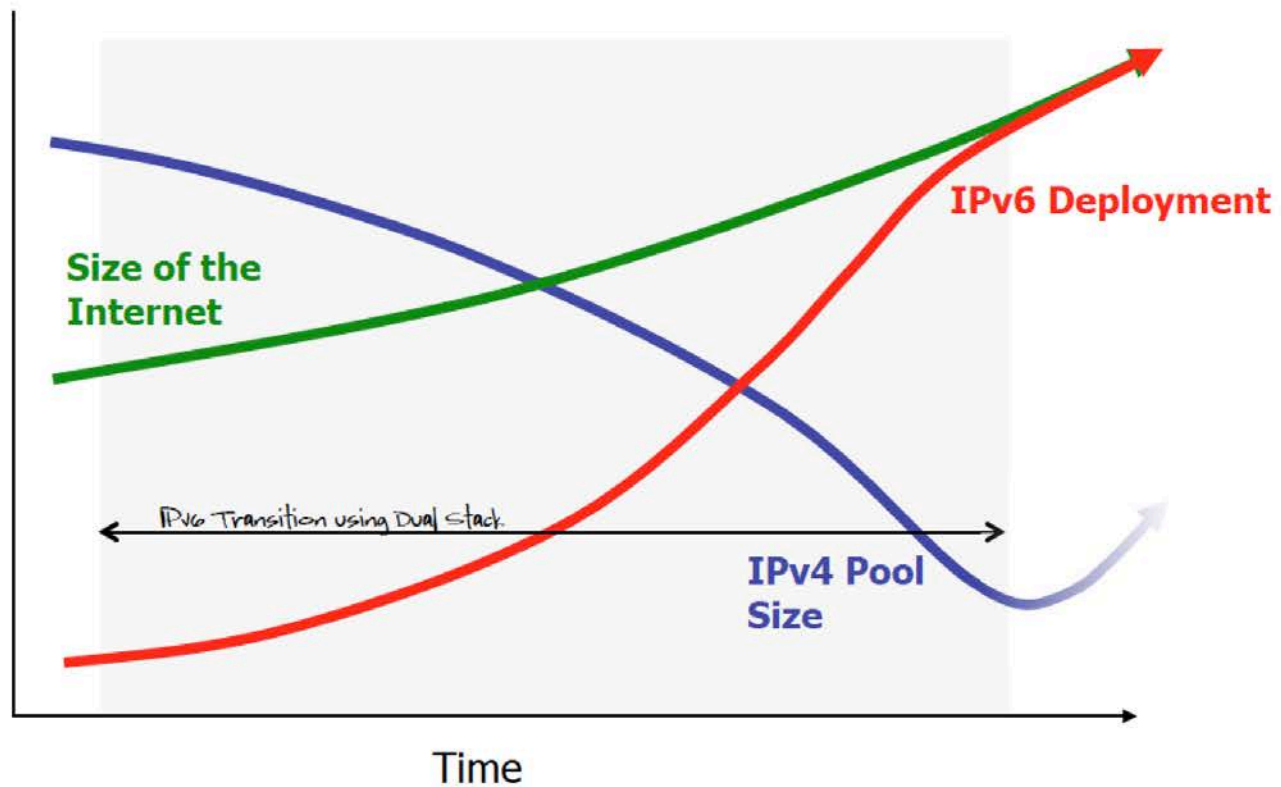


what then?

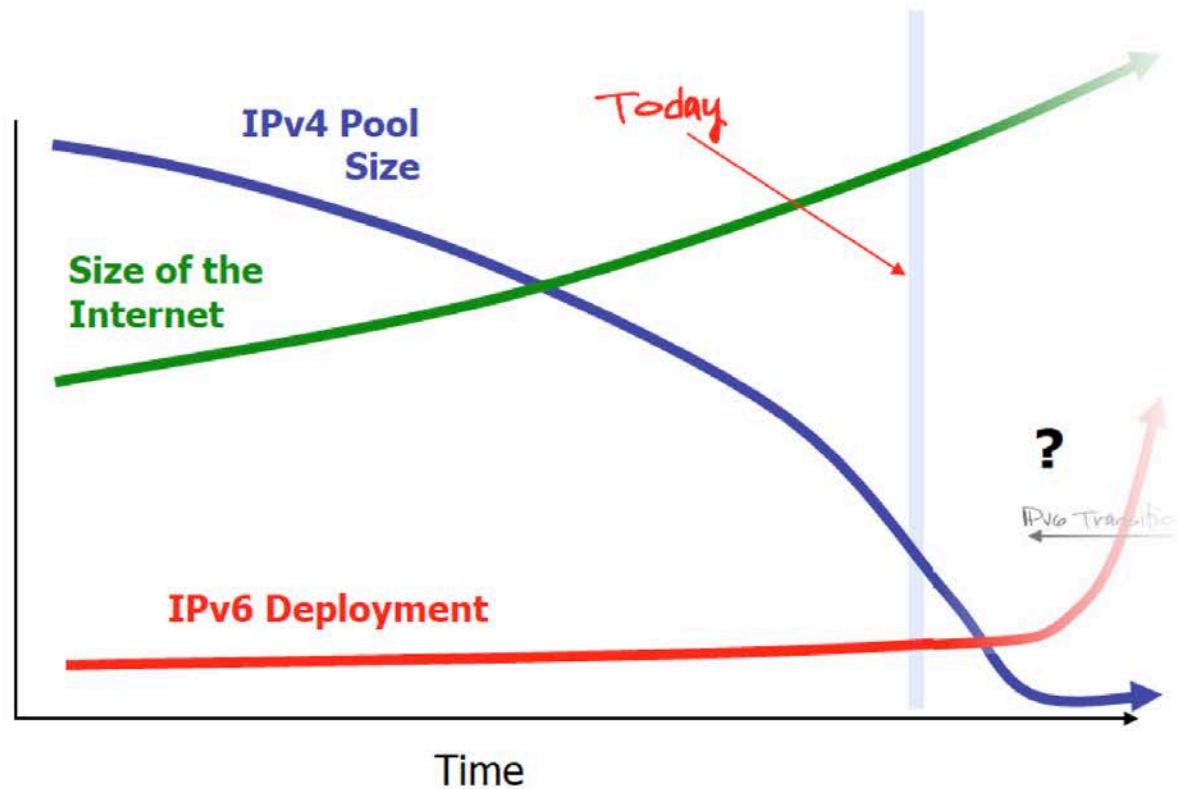


IPV6!

We had this plan ...



what's the revised plan?

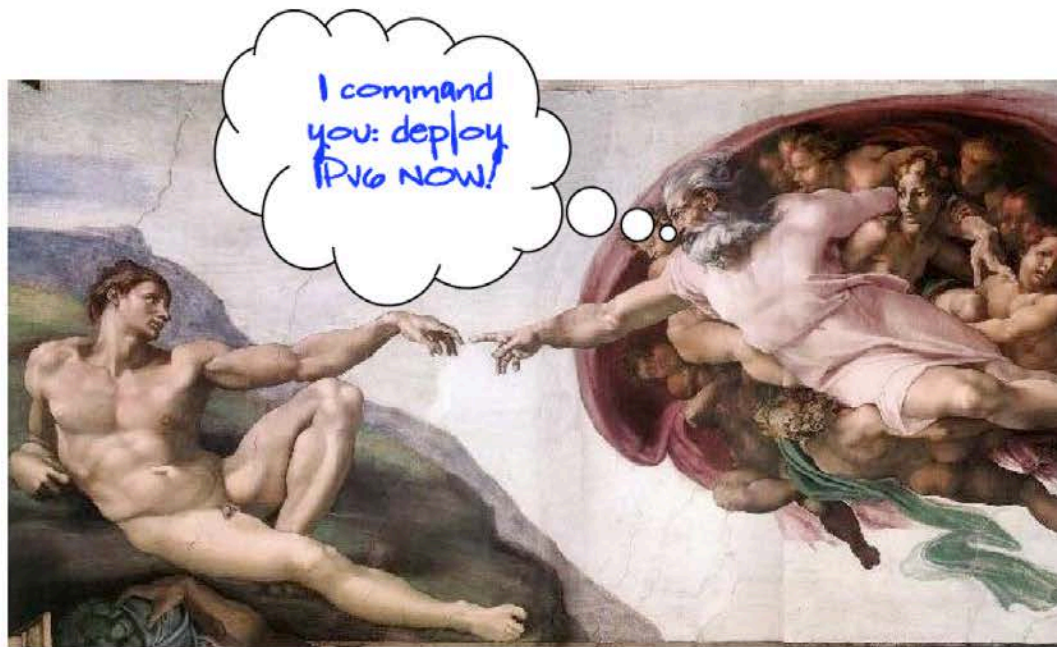


If IPv6 is the answer then...



Plan A: its time to move!

The global internet adopts IPv6 universally
before **January 2009** and completely quits all
use of IPv4 well before address pool
exhaustion occurs



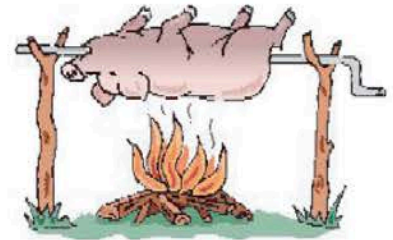
If IPv6 is the answer then..

Plan A: its time to move!

The global Internet, with more than 1.7 billion users, a similar population of end hosts, and hundreds of millions of routers, firewalls, and billions of lines of configuration codes, and hundreds of millions of ancillary support systems, where only a very small proportion are IPv6 aware, , are all upgraded and fielded to work with IPv6 **in the next 120 days**, and then completely quits all use of IPv4 in **10 days later**.



Really



BIG and FAST don't go together!

If IPv6 is the answer then...



Plan B: Dual Stack

Leisurely IPv6 deployment

and

Persist with IPv4 networks using more NATs

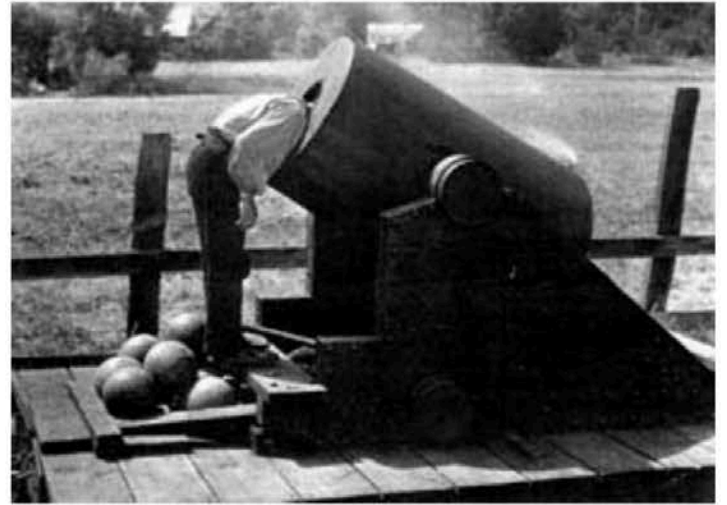
If IPv6 is the answer then...



Plan B: Dual Stack

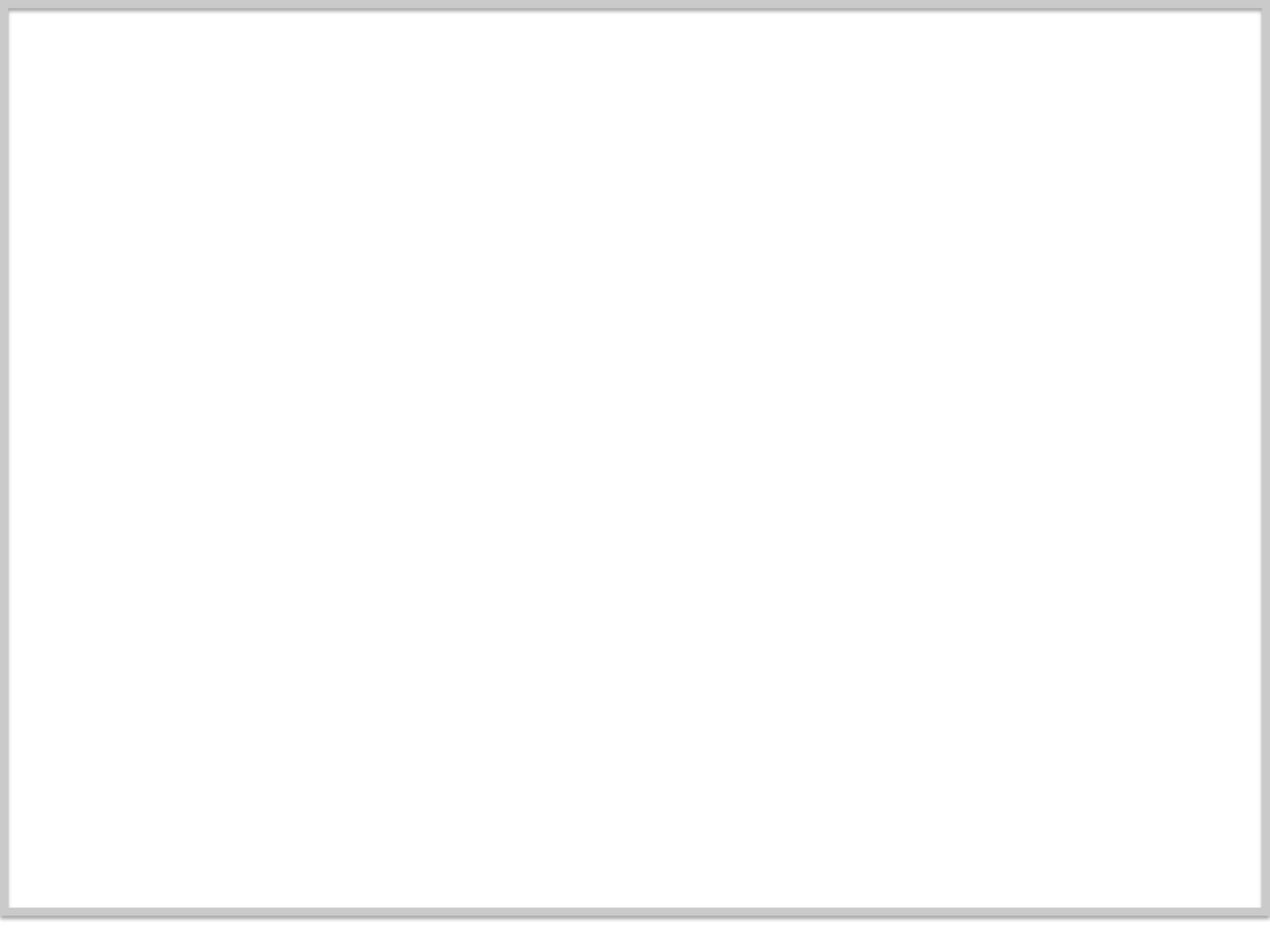
Make IPv4 work using more intense levels of NAT deployment in new products and services for as long as the existing deployed networks continue to use IPv4

This may take a decade or two



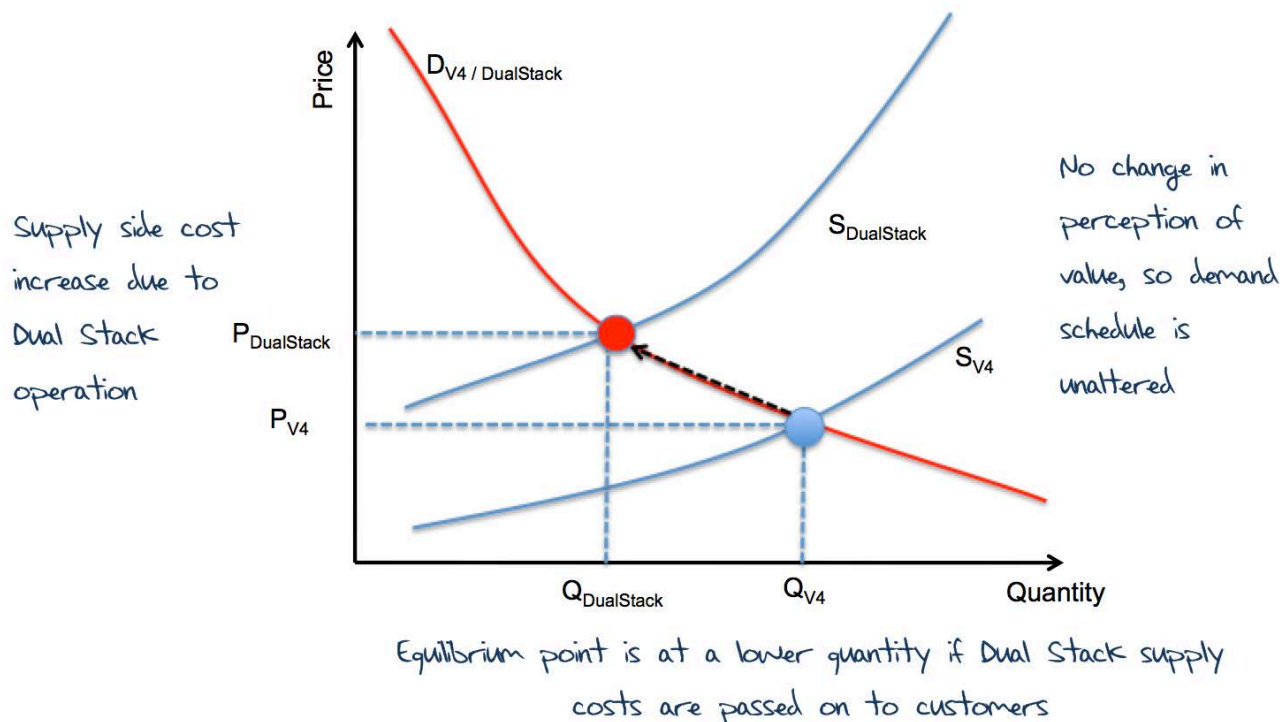
Its just not looking very good is it?

why are we here?



2010 – Invoking Economics!

IPv4 to Dual Stack: The Demand Schedule Shift



2010 – invoking economics!

Is this a bit like the economics of climate change?

Right now individual short term interests are leading the Internet towards collective long term sub-optimal outcomes

At some point very soon the Internet will need some external impetus to restate short term interests to align with common longer term objectives

If we want IPv6 to happen we might need a large kick in the rear to get us there!

2012: Measurement

Counting IPv6...

Some 50% of the Internet's transit ISPs support IPv6 transit

Some 50% of the Internet's host devices have an active IPv6 stack

and the rest run Windows XP!

But only 0.5% of the Internet actually uses IPv6!

and the problem appears to lie in the last mile access infrastructure!

Which brings us to...

6 June 2012



World IPv6 Launch

“This time it’s forever”

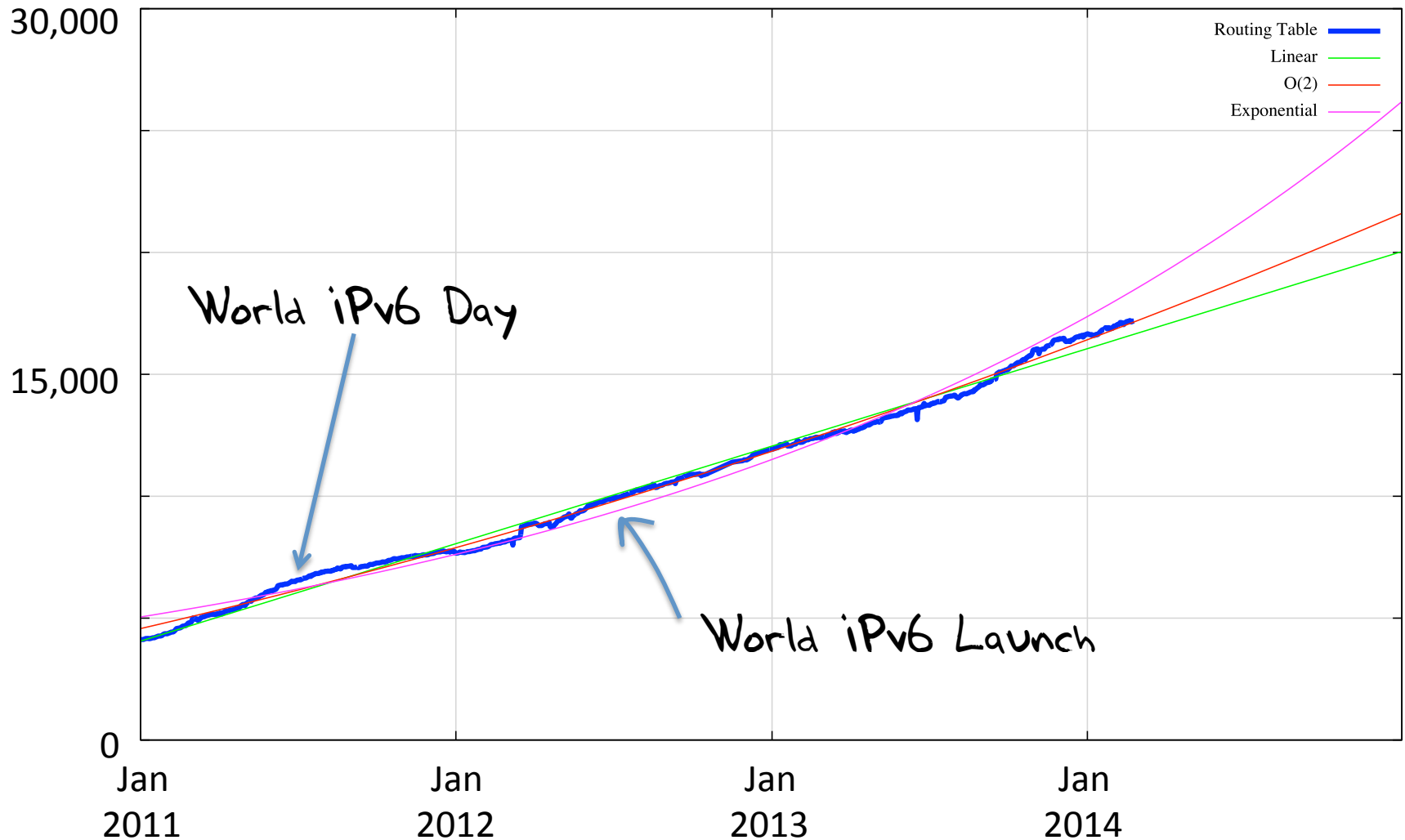
Urging service providers to turn on IPv6, and leave it on.

Reach out to network, access and content providers to start moving in public on IPv6 services

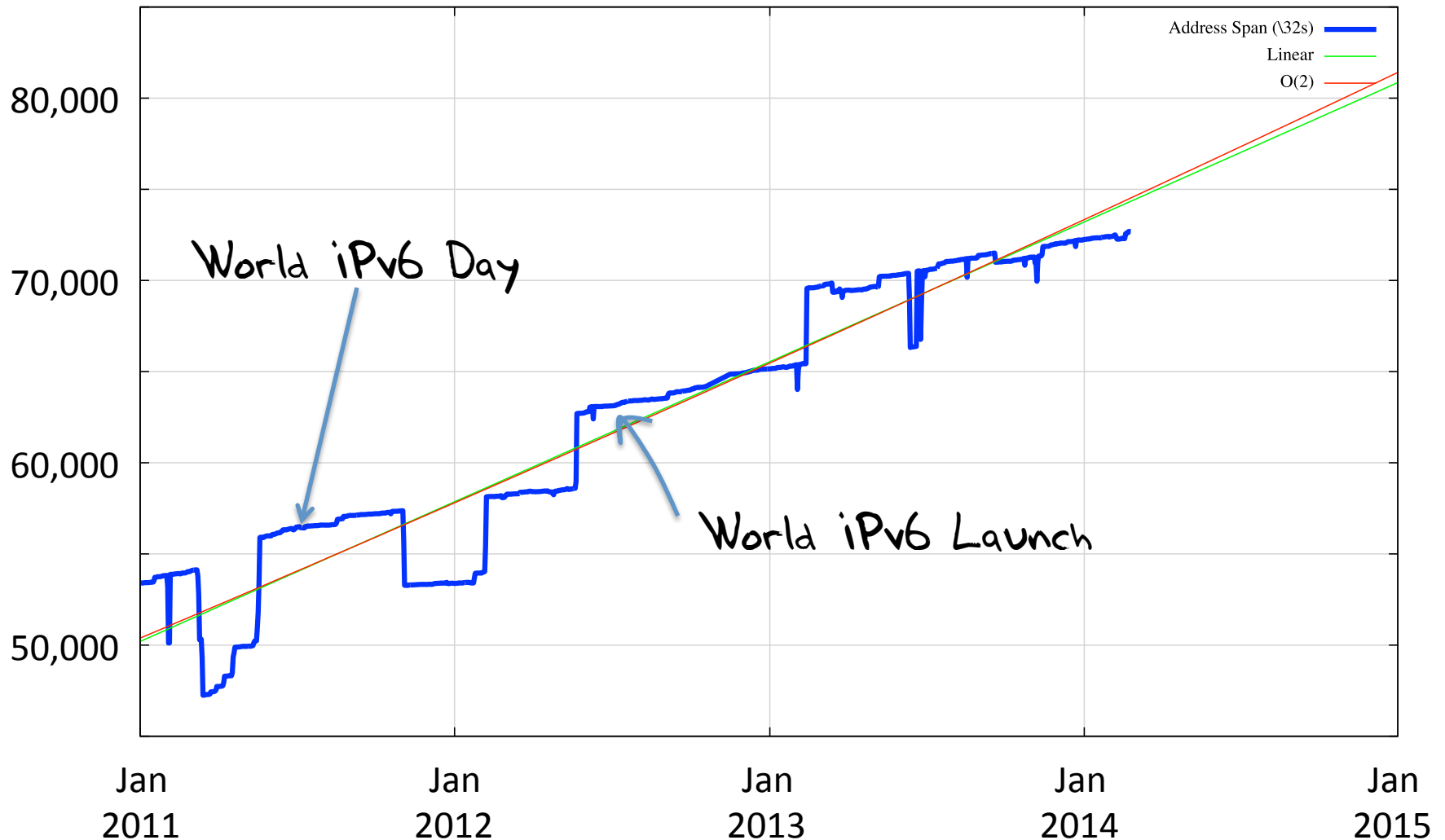
Did it work?

IPv6 BGP Prefix Count

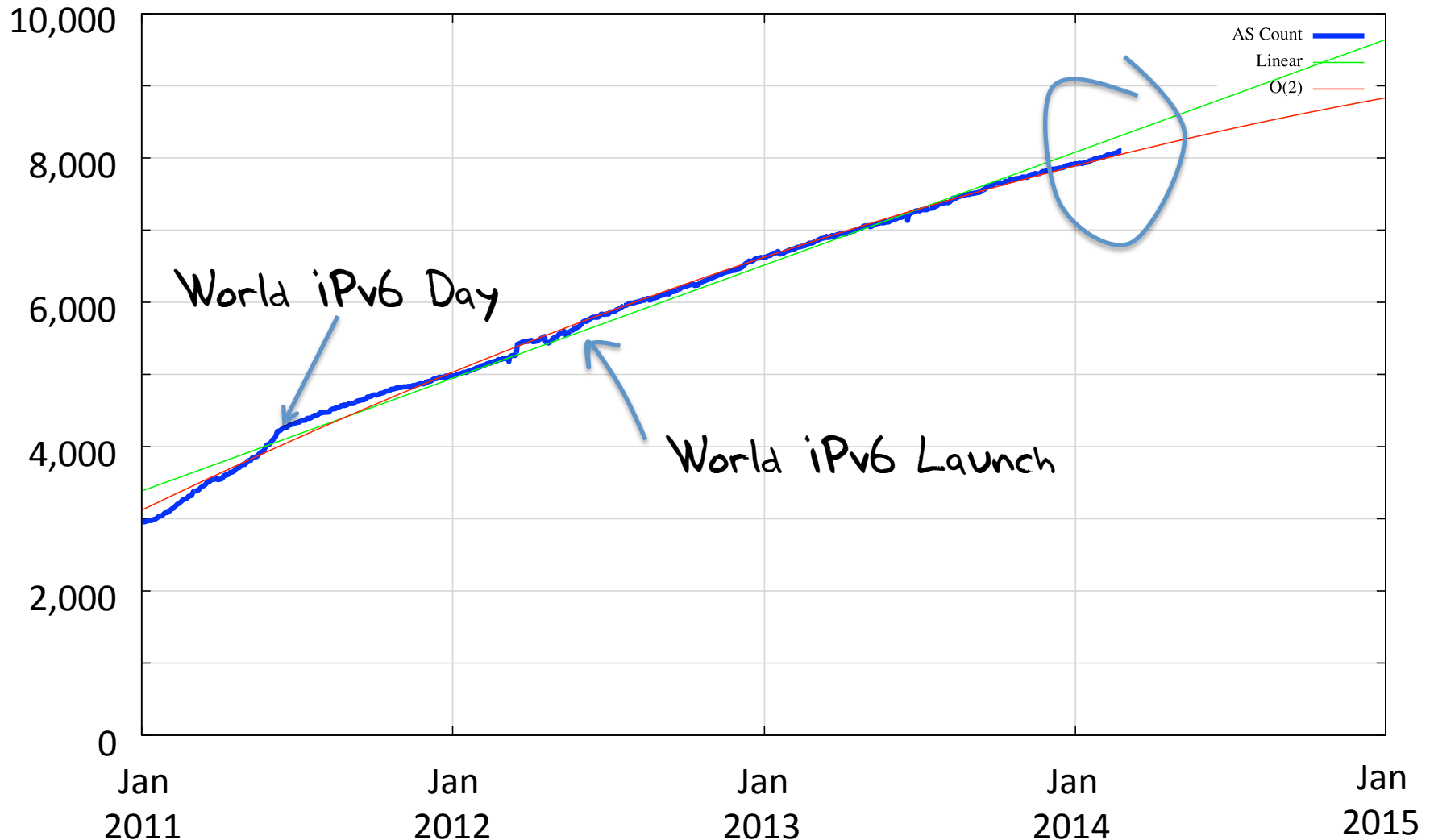
V6 BGP FIB Size



IPv6 Routed Address Span



IPv6 Routed AS Count



IPv6 2011 BGP Vital Statistics

	Jan-13	Jan-14	p.a. rate
Prefix Count	11,500	16,100	+ 40%
Roots	8,451	11,301	+ 34%
More Specifics	3,049	4,799	+ 57%
Address Span (/32s)	65,127	72,245	+ 11%
AS Count	6,560	7,845	+ 20%
Transit	1,260	1,515	+ 20%
Stub	5,300	6,330	+ 19%

IPv6 in 2013

- Overall IPv6 Internet growth in terms of BGP is **20% - 40 % p.a.**
 - 2012 growth rate was ~ 90%.

(Looking at the AS count, if these relative growth rates persist then the IPv6 network would span the same network domain as IPv4 in 16 years time -- 2030!)

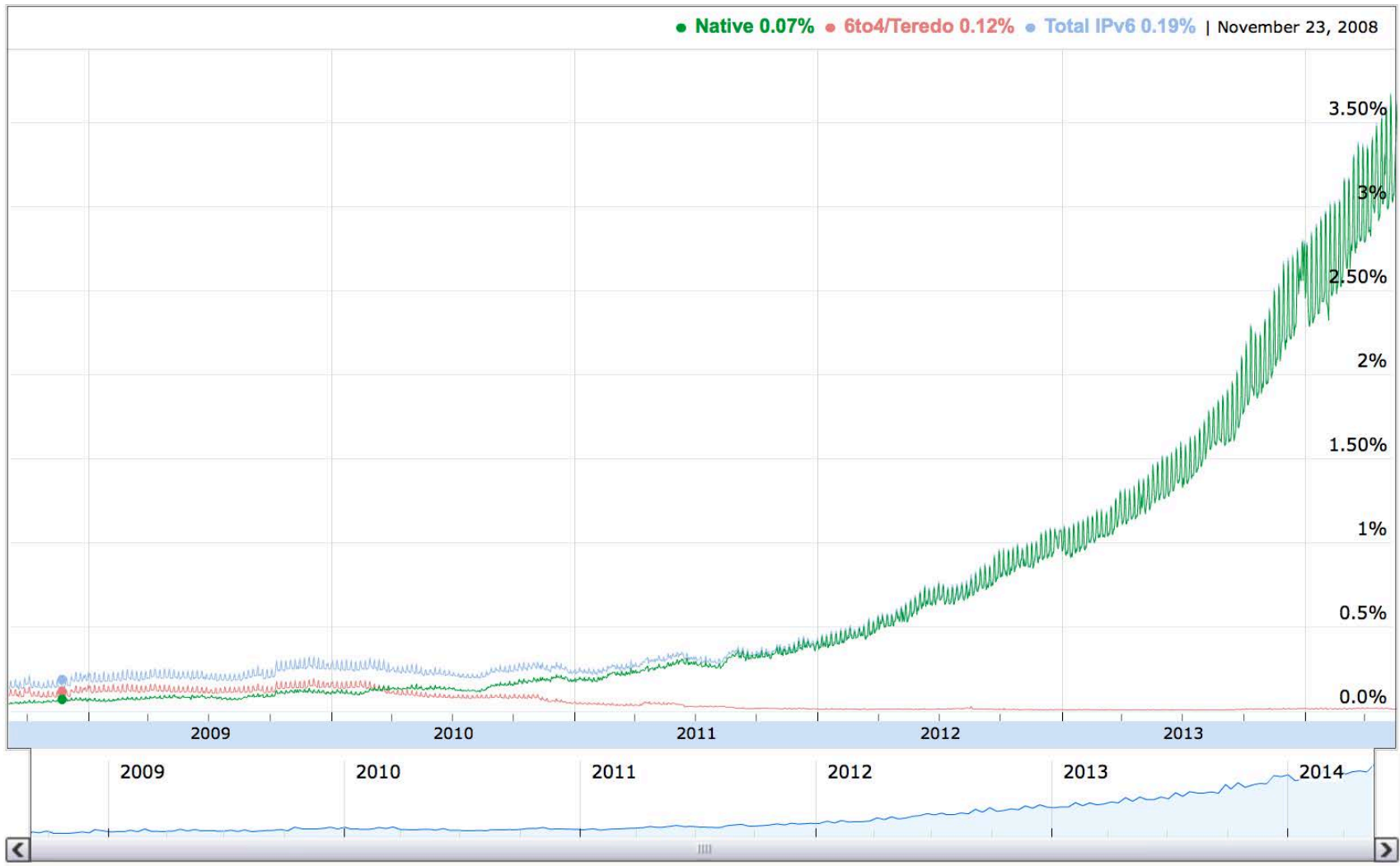
IPv6 – Growth is Slowing

- The rate of growth of the IPv6 Internet is slowing down
- Why?
 - Lack of critical momentum behind IPv6?
 - Saturation of critical market sectors by IPv4?
 - *<some other factor>?*

Some More Questions ...

- What has changed since then?
- Who is deploying IPv6?
- Where are they?

This is what Google see...



And this is what Google see...



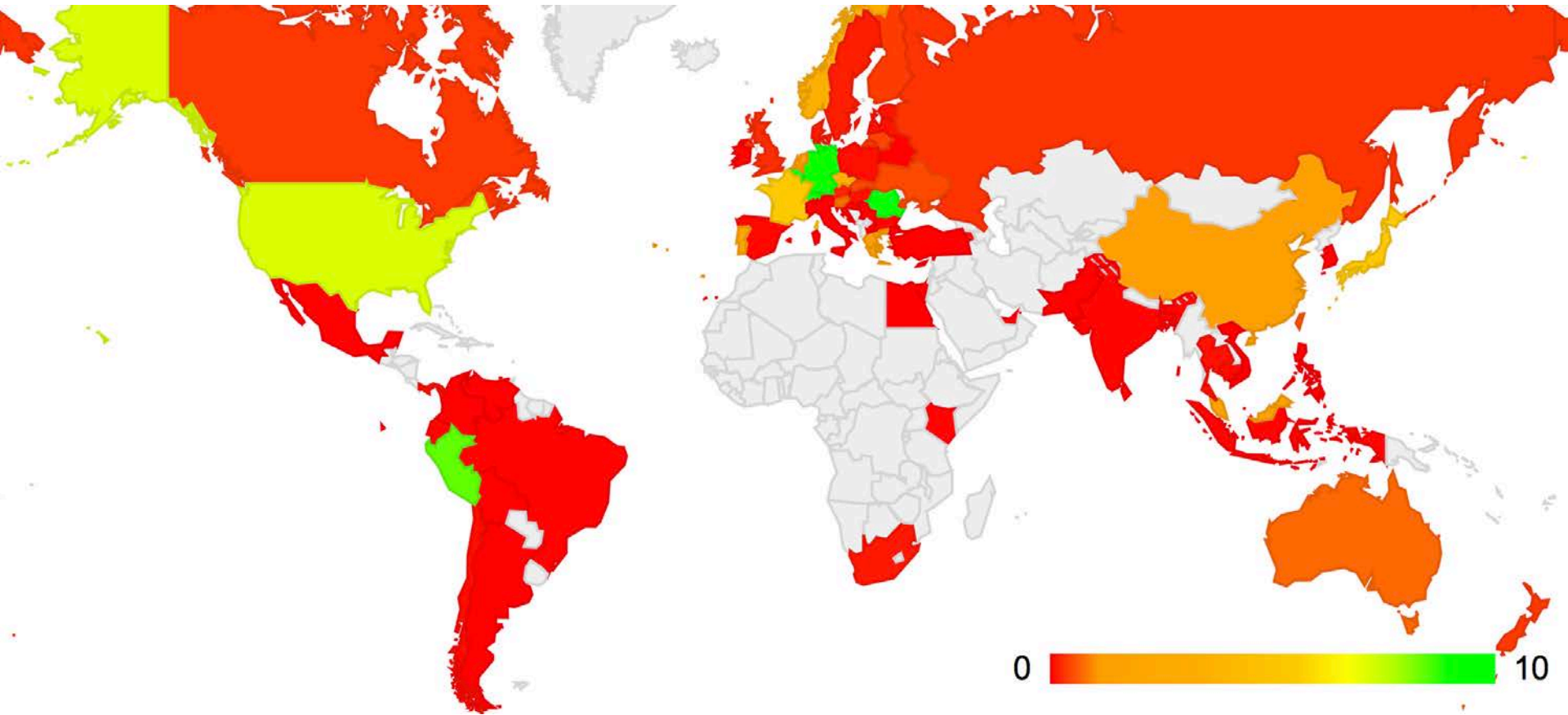
And this is what we see...

When we ask some 300,000 new end users every day about their IPv6 capability we see this...

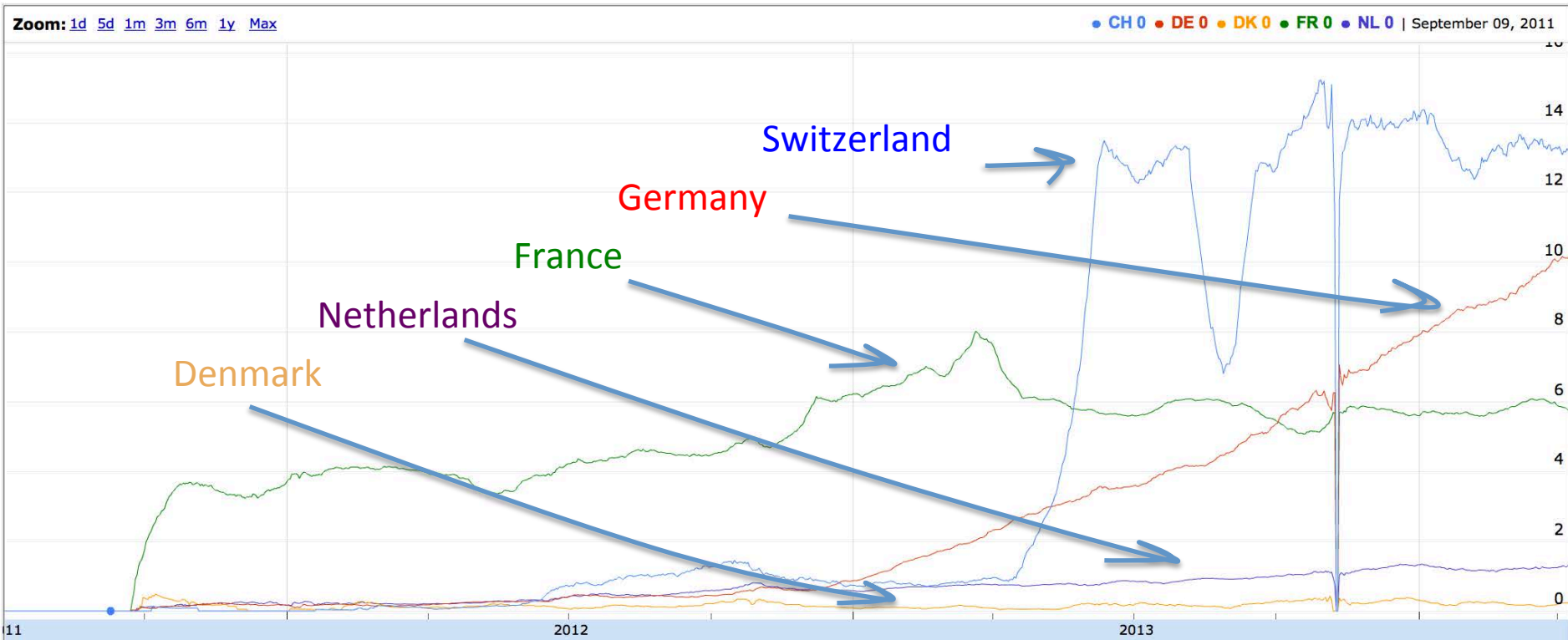
And this is what we see...



And this is what we see...



And this is what we see...



Globally Speaking

- IPv6 did not happen everywhere and all at once in 2012 / 2013
- Some economies have been very active in terms of IPv6 deployment
- So lets look at this on a country-by-country basis...

Where is IPv6?

The National Top 20 – Then and Now

2012

Rank	Economy	% of Internet Users	# of IPv6 Users (est)
1	Romania	7.40%	641,389
2	France	4.03%	2,013,920
3	Luxembourg	2.59%	12,049
4	Japan	1.75%	1,766,799
5	Slovenia	1.07%	15,175
6	United States	1.01%	2,500,684
7	China	1.01%	5,209,030
8	Croatia	0.85%	22,551
9	Switzerland	0.80%	51,575
10	Lithuania	0.66%	13,845
11	Czech Republic	0.55%	39,694
12	Norway	0.51%	23,333
13	Slovakia	0.44%	19,112
14	Russian Fed.	0.39%	238,576
15	Germany	0.32%	217,494
16	Hungary	0.31%	19,896
17	Portugal	0.30%	16,406
18	Netherlands	0.27%	40,870
19	Australia	0.25%	49,425
20	Taiwan	0.24%	38,843

2013

Rank	Economy	% of Internet Users	# of IPv6 Users (est)
1	Romania	10.84%	1,053,237
2	Switzerland	10.72%	700,777
3	Luxembourg	6.96%	32,535
4	France	5.46%	2,824,465
5	Belgium	4.17%	339,651
6	Japan	4.13%	4,137,476
7	Germany	3.24%	2,212,062
8	United States	2.72%	6,768,264
9	Peru	2.42%	273,370
10	Czech Republic	2.12%	157,203
11	Singapore	1.58%	54,060
12	Norway	1.21%	53,677
13	Slovenia	0.92%	13,230
14	China	0.90%	4,651,953
15	Greece	0.78%	44,572
16	Portugal	0.76%	45,408
17	Taiwan	0.72%	120,180
18	Netherlands	0.70%	109,425
19	Australia	0.69%	121,256
20	Slovakia	0.52%	21,169

Where is IPv6?

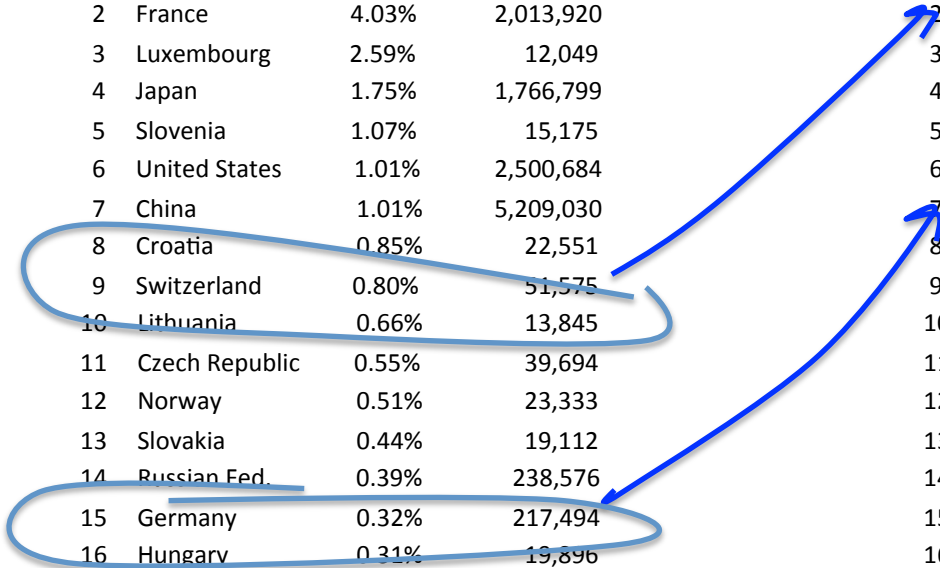
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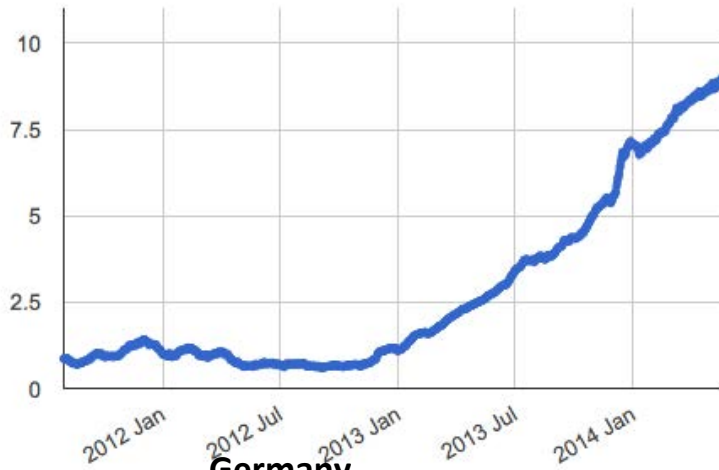
Nationally, who's been active in deploying IPv6 over the past year?

2013

Rank	Economy	Diff (%)	Diff IPv6 User Count
1	Switzerland	+9.92%	+ 649,202
2	Luxembourg	+4.37%	+ 20,486
3	Belgium	+4.07%	+ 331,153
4	Romania	+3.44%	+ 411,848
5	Germany	+2.92%	+1,994,568
6	Peru	+2.41%	+ 272,327
7	Japan	+2.38%	+2,370,677
8	United States	+1.71%	+4,267,580
9	Czech Republic	+1.57%	+ 117,509
10	Singapore	+1.43%	+ 48,524
11	France	+1.43%	+ 810,545
12	Greece	+0.70%	+ 40,530
13	Norway	+0.70%	+ 30,344
14	Taiwan	+0.48%	+ 81,337
15	Portugal	+0.46%	+ 29,002
16	Australia	+0.44%	+ 71,831
17	Netherlands	+0.43%	+ 68,555
18	New Zealand	+0.35%	+ 13,174
19	South Africa	+0.33%	+ 34,022
20	Bosnia and Herz.	+0.32%	+ 8,914

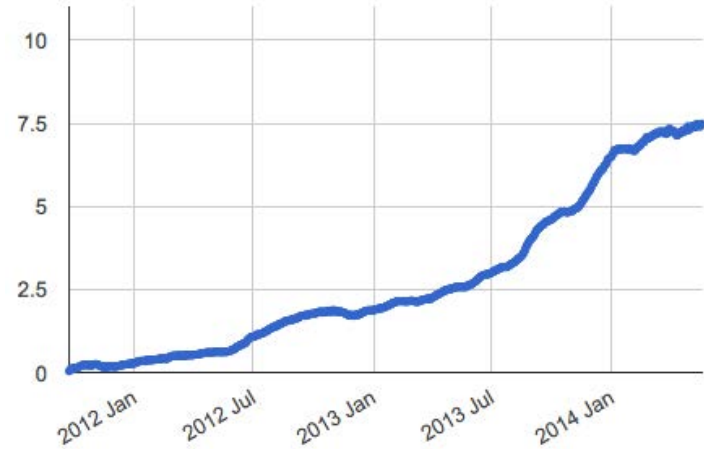
And Some Countries...

IPv6 Preference by Month



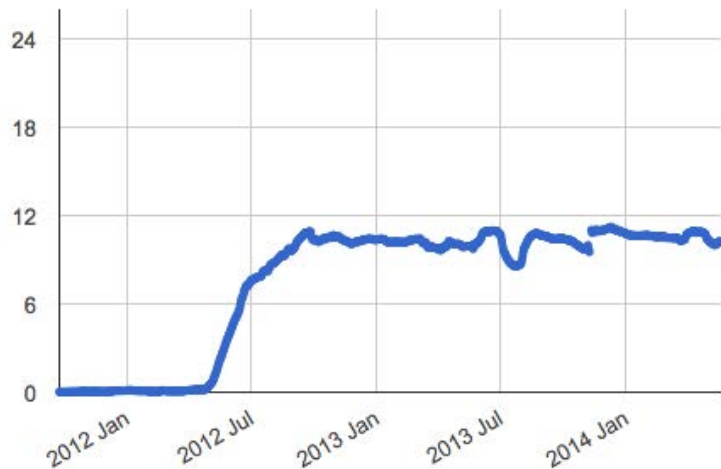
Germany

IPv6 Preference by Month



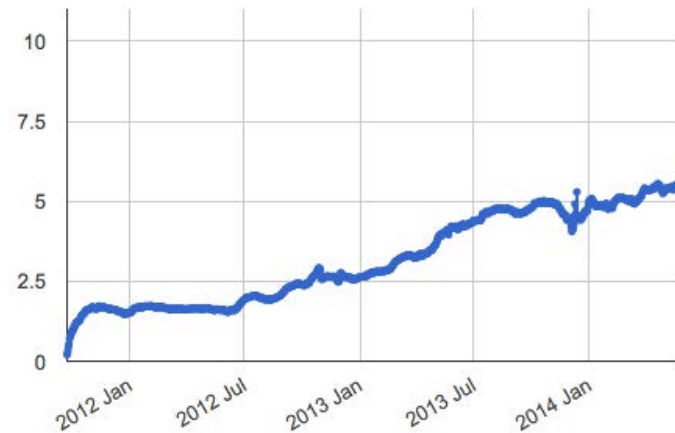
United States

IPv6 Preference by Month



Romania

IPv6 Preference by Month



Japan

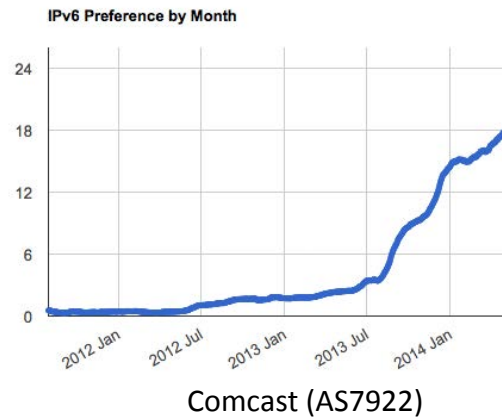
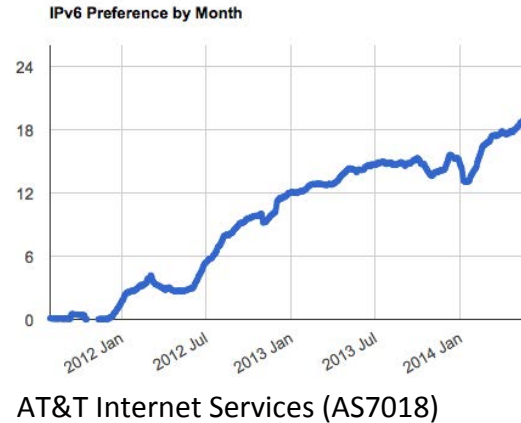
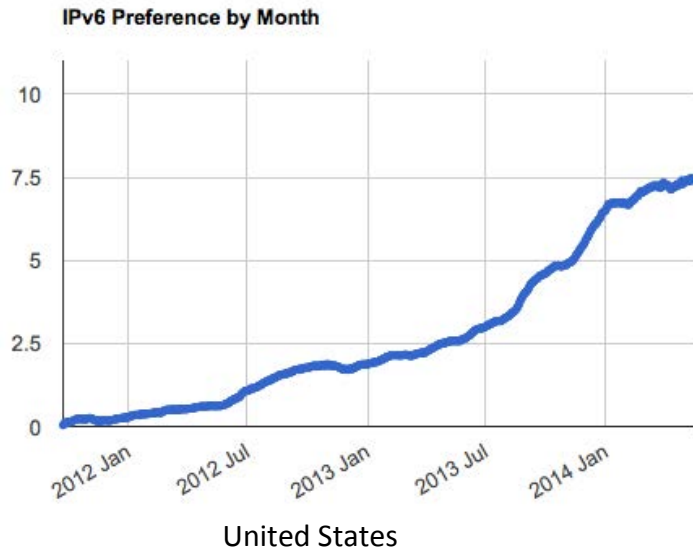
Drilling down to the AS level...

Economy	AS Number	AS Name	2012 IPv6 (%)	2013 IPv6 (%)
United States of America				
	AS6939	Hurricane Electric	29%	37%
	AS22394	Cellco Partnership DBA Verizon Wireless	6%	20%
	AS7018	AT&T Services	6%	15%
	AS3561	Savvis	1%	5%
	AS7922	Comcast	1%	3%
Japan				
	AS2516	KDDI	16%	27%
	AS18126	Chubu Telecomm	0%	23%
	AS17676	Softbank	1%	4%
Germany				
	AS3320	Deutsche Telekom AG	0%	5%
	AS31334	Kabel Deutschland	1%	7%
	AS29562	Kabel BW GmbH	0%	10%
France				
	AS12322	Free SAS	19%	22%
Switzerland				
	AS67722	Swisscomm	0%	23%
	AS559	Switch	11%	18%
Romania				
	AS8708	RCS & RDS SA	11%	24%
Belgium				
	AS12392	Brutele SC	0%	33%
	AS2611	BELNET	2%	22%
Peru				
	AS6147	Telefonica del Peru SA	0%	3%
Czech Republic				
	AS2852	CESNET z.s.p.o.	20%	27%
	AS5610	Telefonica Czech	0%	3%
	AS51154	Internethome; s.r.o.	0%	2%

Economy	AS Number	AS Name	2012 IPv6 (%)	2013 IPv6 (%)
United Kingdom				
	AS786	JANET	51%	68%
	AS13213	UK2 Ltd	0%	23%
Taiwan				
	AS9264	Academic Sinica	0%	21%
	AS1659	Taiwan Academic	2%	8%
Australia				
	AS7575	AARNet	13%	21%
	AS4739	Internode	5%	11%
Netherlands				
	AS3265	XS4ALL Internet	6%	27%
Singapore				
	AS7472	Starhub Internet	0%	13%
	AS4773	MobileOne Ltd.	0%	10%
Greece				
	AS5408	Greek R&D	17%	19%
South Africa				
	AS2018	TENET	0%	3%
Canada				
	AS6453	TATA Comms.	10%	13%
	AS22995	Xplornet Comms	0%	9%
Norway				
	AS224	Uninett	16%	24%
	AS39832	Opera Software	1%	100%
	AS57963	Lynet Internett	0%	56%
Portugal				
	AS3243	PT Comunicacoes	0%	1%
Luxembourg				
	AS6661	Postes et Telecom	4%	14%

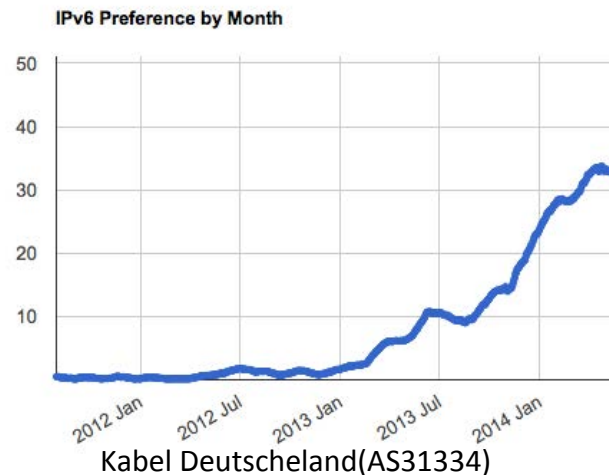
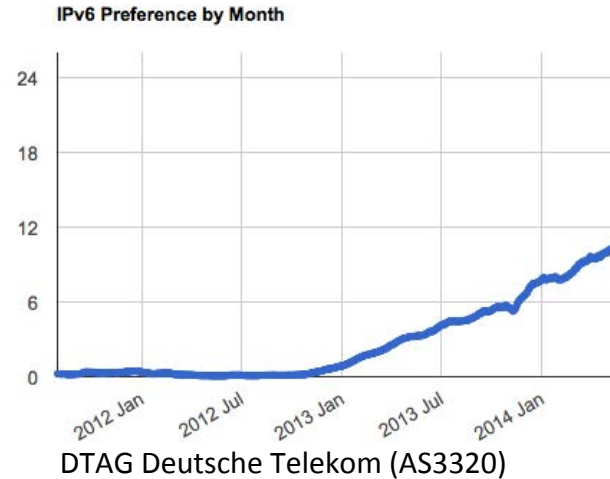
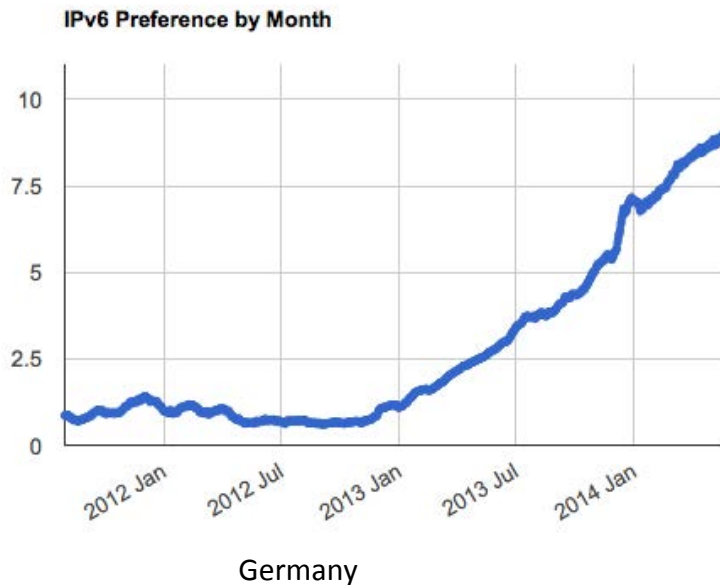
Moving on...

It's not everyone ... but some are moving on with IPv6



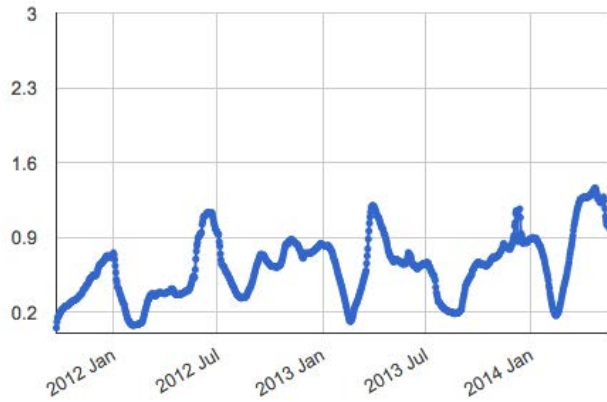
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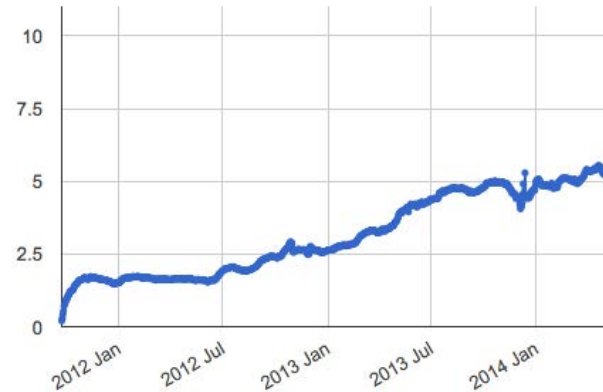
Further afield

IPv6 Preference by Month



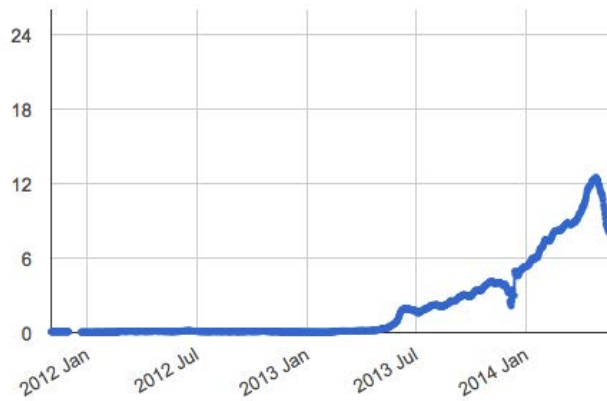
China

IPv6 Preference by Month



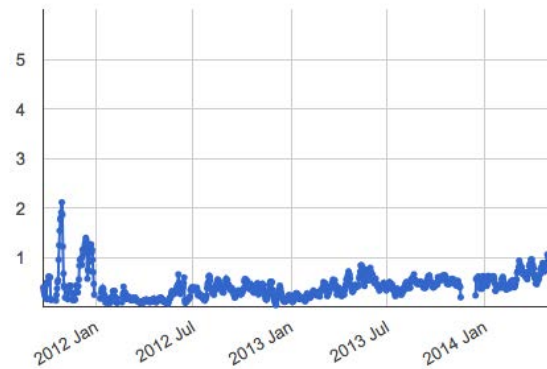
Japan

IPv6 Preference by Month



Singapore

IPv6 Preference by Month



Australia

What are we seeing?

IPv6 deployment is not happening everywhere.

IPv6 is not happening all at once.

But it IS happening.

What are we seeing?

What we appear to be seeing are concentrated areas of quite intense IPv6 activity.

Is IPv6 still “A Waiting Game”?

So far what we have heard from many industry actors about IPv6 is:

“I’m waiting for others. I’ll jump when they jump.”

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In the past year we have seen a number of major commercial network service operators, primarily in the United States, Japan, Germany, France, Switzerland, China and Romania, launch programs that integrate IPv6 services into their mass market retail offerings.

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I'd like to think so!

A question to each of you...

How many IPv6 presentations have you sat through?

☐ 21?

☐ 101?

☐ 1,001?

☒ I don't know - I was comatose by the end!

Thank You!

